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SPECIFICATION

TITLE OF THE INVENTION AN OPTICAL RECORDING MEDIUM

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BACKGROUND OF THE INVENTION

The present invention relates to a method for determining the power of a laser beam, a method for determining a critical parameter used for determining the power of a laser beam, an optical recording medium and a data recording apparatus and, particularly, to a method for determining the power of a laser beam which can determine the recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded in a data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained, a method for determining a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam to be projected onto a data rewritable type optical recording medium so that jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained, a data rewritable type optical recording medium in which a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded therein can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained, a data

recording apparatus storing a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam to be projected onto a data rewritable type optical recording medium so that jitter of a reproduced signal obtained by reproducing data
5 recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained, and a data recording apparatus storing an optimum recording power of a laser beam to be projected onto a data rewritable optical recording medium so
10 that jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

15 DESCRIPTION OF THE PRIOR ART

Optical recording discs such as the CD, DVD and the like have been widely used as recording media for recording digital data.

As a method for recording data in an optical recording medium, there has been widely used a method for modulating data to be recorded
20 into lengths of a recording mark and a blank region. For example, in a DVD-RW which is an optical recording medium in which data can be rewritten by the user, recording marks and blank regions having lengths corresponding to a 3T signal to an 11T signal and a 14T signal are used for recording data therein.

25 In the case where data are to be recorded in a recording layer containing a phase change material of a data rewritable optical recording medium, a laser beam whose power is modulated is projected onto the recording layer along a track formed on the optical recording medium,

thereby forming an amorphous region in the recording layer so that the thus formed amorphous region of the recording layer is used as a recording mark and a crystalline region of the recording layer is used as a blank region.

5 In the case where a recording mark is to be formed at a predetermined region of the recording layer, the power of a laser beam is modulated to a sufficiently high recording power P_w , the laser beam is projected onto the predetermined region of the recording layer, thereby heating the predetermined layer of the recording layer to a temperature
10 equal to or higher than the melting point of a phase change material and the power of the laser beam is then modulated to a bottom power P_b lower than the recording power P_w , thereby quickly cooling the predetermined layer of the recording layer and changing the phase thereof from a crystalline phase to an amorphous phase.

15 To the contrary, in the case where a recording mark formed in the recording layer is to be erased, the power of the laser beam is modulated to an erasing power P_e higher than the bottom power P_b and lower than the recording power P_w , the laser beam is projected onto a region of the recording layer where the recording mark is formed, thereby heating the
20 region of the recording layer to a temperature equal to or higher than the crystallized temperature of the phase change material and the region of the recording layer is then gradually cooled, thereby crystallizing the phase change material in an amorphous phase.

 In this manner, it is possible to form a recording mark in the
25 recording layer and erase the recording mark formed in the recording mark by modulating the power of a laser beam to be projected onto the recording layer between the recording power P_w , the erasing power P_e and the bottom power P_b different from each other, thereby directly

overwriting a recording mark formed in the recording layer with a different recording mark.

However, in a data rewritable type optical recording medium, when data are to be written in the recording layer on a particular track of a recording layer, the reduction in carrier levels of data written on opposite tracks of the track, namely, so-called cross erasing of data sometimes occurs.

Particularly, in a next-generation type optical recording medium that offers increased recording density and has an extremely high data transfer rate, cross erasing of data tends to occur in comparison with a conventional optical recording medium.

More specifically, in a next-generation type optical recording medium, since in order to achieve high data transfer rate, it is required to record data at a higher linear recording velocity than that for recording data in a conventional optical recording medium and it is required to set a recording power of a laser beam to a higher level as the linear recording velocity is higher, when data are to be written on a particular track of a recording layer, tracks on the opposite sides of the track are liable to be subjected to thermal influence from the track on which data are to be written and cross erasing of data tends to occur.

Further, in a next-generation type optical recording medium, since a ratio TP/D of a track pitch TP to a spot diameter of the laser beam is small, when data are to be written on a particular track of a recording layer, cross erasing of data tends to occur.

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SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method for determining the power of a laser beam which can determine the

recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded in a data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest
5 level can be obtained.

It is another object of the present invention to provide a method for determining a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam to be projected onto a data rewritable type optical recording medium so that
10 jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

It is a further object of the present invention to provide a data
15 rewritable type optical recording medium in which a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded therein can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced
20 signal having the highest level can be obtained.

It is a still further object of the present invention to provide a data recording apparatus storing a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam to be projected onto a data rewritable type optical recording
25 medium so that jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

It is a yet further object of the present invention to provide a data recording apparatus storing an optimum recording power of a laser beam to be projected onto a data rewritable optical recording medium so that jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

The above objects of the present invention can be accomplished by a method for determining a power of a laser beam which is adapted for determining a recording power of the laser beam to be projected onto a data rewritable type optical recording medium for recording data therein, the method for determining a power of a laser beam comprising steps of recording a first test signal in the data rewritable type optical recording medium while varying a level of the recording power of the laser beam, measuring, for each of the levels of the recording power of the laser beam, an amplitude A_0 of a reproduced signal obtained by reproducing the first test signal before the first test signal is influenced by cross erasing of data, an amplitude A_1 and jitter J_1 of a reproduced signal obtained by reproducing the first test signal after the first test signal was once influenced by cross erasing of data and an amplitude A_s and jitter J_s of a reproduced signal obtained by reproducing the first test signal after an influence of cross erasing of data on the first test signal was saturated, calculating a first parameter for each of the levels of the recording power as a function of a difference between the amplitude A_0 of the reproduced signal obtained reproducing the first test signal before the first test signal is influenced by cross erasing of data and the amplitude A_1 of the reproduced signal obtained by reproducing the first test signal after the first test signal was once influenced by cross erasing of data, calculating a

second parameter for each of the levels of the recording power as a function of a difference between the amplitude $A1$ of the reproduced signal obtained by reproducing the first test signal after the first test signal was once influenced by cross erasing of data and the amplitude As of the reproduced
5 signal obtained by reproducing the first test signal after the influence of cross erasing of data on the first test signal was saturated, calculating a third parameter as a function of a difference between jitter Js of the reproduced signal obtained by reproducing the first test signal after the influence of cross erasing of data on the first test signal was saturated and
10 jitter $J1$ of the reproduced signal obtained by reproducing the first test signal after the first test signal was once influenced by cross erasing of data, obtaining a value of the first parameter corresponding to a value of the second parameter when the third parameter is equal to a tolerance, thereby determining a critical parameter, recording a second test signal in
15 the data rewritable type optical recording medium while varying a level of the recording power of the laser beam, judging whether or not signal characteristics of a reproduced signal obtained by reproducing the second test signal recorded in the data rewritable type optical recording medium satisfy reference conditions, measuring, for each of the levels of the
20 recording power of the laser beam, when the signal characteristics of the reproduced signal obtained by reproducing the second test signal recorded in the data rewritable type optical recording medium satisfy the reference conditions, an amplitude $AA0$ of the reproduced signal obtained by reproducing the second test signal before the second test signal is
25 influenced by cross erasing of data and an amplitude $AA1$ of the reproduced signal obtained by reproducing the second test signal after the first test signal was once influenced by cross erasing of data, calculating a fourth parameter based on the amplitudes $AA0$ and $AA1$ of the reproduced

signals obtained by reproducing the second test signals as a function of a difference between the amplitude AA0 of the reproduced signal obtained by reproducing the second test signal before the second test signal is influenced by cross erasing of data and the amplitude AA1 of the reproduced signal obtained by reproducing the second test signal after the first test signal was once influenced by cross erasing of data, comparing the critical parameter and the fourth parameter, and determining the recording power of the laser beam at which the fourth parameter was obtained as an optimum recording power when the fourth parameter is equal to or lower than the critical parameter.

According to the present invention, it is possible to determine an optimum recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded in a data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained only by when the signal characteristics of the reproduced signal obtained by recording the second test signal in the data rewritable type optical recording medium while varying a level of the recording power of the laser beam and reproducing the second test signal recorded in the data rewritable type optical recording medium satisfy the reference conditions, measuring, for each of the levels of the recording power of the laser beam, an amplitude AA0 of the reproduced signal obtained by reproducing the second test signal before the second test signal is influenced by cross erasing of data and an amplitude AA1 of the reproduced signal obtained by reproducing the second test signal after the first test signal was once influenced by cross erasing of data, calculating a fourth parameter based on the amplitudes AA0 and AA1 of the reproduced signals obtained by reproducing the test signal as a function of the

difference between the amplitude AA0 of the reproduced signal obtained by reproducing the second test signal before the second test signal is influenced by cross erasing of data and the amplitude AA1 of the reproduced signal obtained by reproducing the second test signal after the first test signal was once influenced by cross erasing of data, and comparing the thus calculated fourth parameter with a critical parameter determined in advance.

In a preferred aspect of the present invention, the method for determining a power of a laser beam comprises steps of setting the recording power of the laser beam to a predetermined level, sequentially projecting the laser beam onto a first track and a second track formed on the data rewritable type optical recording medium to be adjacent with each other in this order, thereby recording the second test signal thereon, reproducing the second test signal recorded on the first track, judging whether or not signal characteristics of the thus obtained reproduced signal satisfy reference conditions, changing the level of the recording power of the laser beam and recording the second test signal onto the first track and the second track formed on the data rewritable type optical recording medium to be adjacent with each other in this order when the signal characteristics of the reproduced signal do not satisfy the reference conditions, until signal characteristics of a reproduced signal obtained by reproducing the second test signal recorded on the first track satisfy the reference conditions, reproducing the second test signal recorded on the first track and measuring an amplitude of the thus obtained reproduced signal, thereby obtaining the amplitude AA1, reproducing the second test signal recorded on the second track and measuring an amplitude of the thus obtained reproduced signal, thereby obtaining the amplitude AA0, and determining the fourth parameter as a function of a difference

between the amplitude AA0 of the reproduced signal obtained from the second track and the amplitude AA1 of the reproduced signal obtained from the first track.

In a preferred aspect of the present invention, the method for
5 determining a power of a laser beam comprises steps of setting the recording power of the laser beam to a predetermined level, sequentially projecting the laser beam onto a third track, a fourth track and a fifth track formed on the data rewritable type optical recording medium to be adjacent with each other in this order, thereby recording the first test
10 signal thereon, reproducing the first test signal recorded on the fourth track, measuring an amplitude and jitter of the thus obtained reproduced signal, thereby obtaining the amplitude A1 and the jitter J1, reproducing the first test signal recorded on the fifth track, measuring an amplitude of the thus obtained reproduced signal, thereby obtaining the amplitude A0,
15 calculating the first parameter, directly overwriting the first test signal recorded on the third track and the first test signal recorded on the fifth track with the first test signal until an influence of cross erasing of data on the first test signal recorded on the fourth track has become saturated, reproducing the first test signal recorded on the fourth track, measuring
20 an amplitude and jitter of the thus obtained reproduced signal, thereby obtaining the amplitude As and the jitter Js, calculating the second parameter and the third parameter, repeatedly performing the above identified steps while varying a level of the recording power of the laser beam by α within a predetermined range, and calculating the first
25 parameter, the second parameter and the third parameter for each of the levels of the recording power of the laser beam.

The above and other objects of the present invention can be also accomplished by a method for determining a critical parameter used for

determining a recording power of a laser beam to be projected onto a data rewritable type optical recording medium for recording data therein, the method for determining a critical parameter used for determining the recording power of the laser beam comprising steps of setting the recording power of the laser beam to a predetermined level, sequentially projecting the laser beam onto a first track, a second track and a third track formed on the data rewritable type optical recording medium to be adjacent with each other in this order, thereby recording a first test signal thereon, reproducing the first test signal recorded on the second track, measuring an amplitude A1 and jitter J1 of the thus obtained reproduced signal, reproducing the first test signal recorded on the third track, measuring an amplitude A1 of the thus obtained reproduced signal, calculating a first parameter as a function of a difference between the amplitude A0 of the reproduced signal obtained from the third track and the amplitude A1 of the reproduced signal obtained from the second track, directly overwriting the first test signal recorded on the first track and the first test signal recorded on the third track with the first test signal until an influence of cross erasing of data on the first test signal recorded on the second track has become saturated, reproducing the first test signal recorded on the second track, measuring an amplitude As and jitter Js of the thus obtained reproduced signal, calculating a second parameter as a function of a difference between the amplitude A1 of the reproduced signal and the amplitude A10 of the reproduced signal, calculating a third parameter as a function of a difference between the jitter Js of the reproduced signal and the jitter J1 of the reproduced signal, repeatedly performing the above identified steps while varying a level of the recording power of the laser beam by α within a predetermined range, calculating the first parameter, the second parameter and the third parameter for each of the levels of the

recording power of the laser beam, obtaining a value of the first parameter corresponding to a value of the second parameter when the third parameter is equal to a tolerance, and determining the thus obtained value of the first parameter as a critical parameter.

- 5 The above and other objects of the present invention can be also accomplished by a data rewritable type optical recording medium recorded with a critical parameter used for determining a recording power of a laser beam, the critical parameter being determined by setting the recording power of the laser beam to a predetermined level, sequentially projecting
- 10 the laser beam onto a first track, a second track and a third track formed thereon to be adjacent with each other in this order, thereby recording a first test signal thereon, reproducing the first test signal recorded on the second track, measuring an amplitude A1 and jitter J1 of the thus obtained reproduced signal, reproducing the first test signal recorded on
- 15 the third track, measuring an amplitude A1 of the thus obtained reproduced signal, calculating a first parameter as a function of a difference between the amplitude A0 of the reproduced signal obtained from the third track and the amplitude A1 of the reproduced signal obtained from the second track, directly overwriting the first test signal
- 20 recorded on the first track and the first test signal recorded on the third track with the first test signal until an influence of cross erasing of data on the first test signal recorded on the second track has become saturated, reproducing the first test signal recorded on the second track, measuring an amplitude As and jitter Js of the thus obtained reproduced signal,
- 25 calculating a second parameter as a function of a difference between the amplitude A1 of the reproduced signal and the amplitude A10 of the reproduced signal, calculating a third parameter as a function of a difference between the jitter Js of the reproduced signal and the jitter J1 of

the reproduced signal, repeatedly performing the above identified steps while varying a level of the recording power of the laser beam by α within a predetermined range, calculating the first parameter, the second parameter and the third parameter for each of the levels of the recording power of the laser beam, and obtaining a value of the first parameter
5 corresponding to a value of the second parameter when the third parameter is equal to a tolerance.

The above and other objects of the present invention can be also accomplished by a data recording apparatus storing a critical parameter
10 used for determining a recording power of a laser beam so as to be associated with ID data for identifying a kind of an optical recording medium, the critical parameter being determined by setting the recording power of the laser beam to a predetermined level, sequentially projecting the laser beam onto a first track, a second track and a third track formed
15 on the data rewritable type optical recording medium to be adjacent with each other in this order, thereby recording a first test signal thereon, reproducing the first test signal recorded on the second track, measuring an amplitude A_1 and jitter J_1 of the thus obtained reproduced signal, reproducing the first test signal recorded on the third track, measuring an
20 amplitude A_1 of the thus obtained reproduced signal, calculating a first parameter as a function of a difference between the amplitude A_0 of the reproduced signal obtained from the third track and the amplitude A_1 of the reproduced signal obtained from the second track, directly overwriting the first test signal recorded on the first track and the first test signal
25 recorded on the third track with the first test signal until an influence of cross erasing of data on the first test signal recorded on the second track has become saturated, reproducing the first test signal recorded on the second track, measuring an amplitude A_s and jitter J_s of the thus obtained

reproduced signal, calculating a second parameter as a function of a difference between the amplitude A1 of the reproduced signal and the amplitude A10 of the reproduced signal, calculating a third parameter as a function of a difference between the jitter Js of the reproduced signal and the jitter J1 of the reproduced signal, repeatedly performing the above identified steps while varying a level of the recording power of the laser beam by α within a predetermined range, calculating the first parameter, the second parameter and the third parameter for each of the levels of the recording power of the laser beam, and obtaining a value of the first parameter corresponding to a value of the second parameter when the third parameter is equal to a tolerance.

The above and other objects of the present invention can be also accomplished by a data recording apparatus storing an optimum recording power of a laser beam so as to be associated with ID data for identifying a kind of an optical recording medium, the optimum recording power of the laser beam being determined by setting the recording power of the laser beam to a predetermined level, sequentially projecting the laser beam onto a first track, a second track and a third track formed on the data rewritable type optical recording medium to be adjacent with each other in this order, thereby recording a first test signal thereon, reproducing the first test signal recorded on the second track, measuring an amplitude A1 and jitter J1 of the thus obtained reproduced signal, reproducing the first test signal recorded on the third track, measuring an amplitude A1 of the thus obtained reproduced signal, calculating a first parameter as a function of a difference between the amplitude A0 of the reproduced signal obtained from the third track and the amplitude A1 of the reproduced signal obtained from the second track, directly overwriting the first test signal recorded on the first track and the first test signal recorded on the

third track with the first test signal until an influence of cross erasing of data on the first test signal recorded on the second track has become saturated, reproducing the first test signal recorded on the second track, measuring an amplitude A_s and jitter J_s of the thus obtained reproduced signal, calculating a second parameter as a function of a difference between the amplitude A_1 of the reproduced signal and the amplitude A_{10} of the reproduced signal, calculating a third parameter as a function of a difference between the jitter J_s of the reproduced signal and the jitter J_1 of the reproduced signal, repeatedly performing the above identified steps while varying a level of the recording power of the laser beam by α within a predetermined range, calculating the first parameter, the second parameter and the third parameter for each of the levels of the recording power of the laser beam, obtaining a value of the first parameter corresponding to a value of the second parameter when the third parameter is equal to a tolerance, thereby determining a critical parameter used for determining the recording power of the laser beam, setting the recording power of the laser beam to a predetermined level, sequentially projecting the laser beam onto a fourth track and a fifth track formed on the data rewritable type optical recording medium to be adjacent with each other in this order, thereby recording a second test signal thereon, reproducing the second test signal recorded on the fourth track, judging whether or not signal characteristics of the thus obtained reproduced signal satisfy reference conditions, changing the level of the recording power of the laser beam and projecting the laser beam onto the fourth track and the fifth track formed on the data rewritable type optical recording medium to be adjacent with each other, thereby recording the second test signal thereon and reproducing the second test signal recorded on the fourth track when the signal characteristics of the reproduced

signal do not satisfy the reference conditions, until the signal characteristics of the thus obtained reproduced signal has satisfied the reference conditions, reproducing the second test signal recorded on the fourth track to measure an amplitude AA1 of the thus obtained reproduced
5 signal, reproducing the second test signal recorded on the fifth track to measure an amplitude AA0 of the thus obtained reproduced signal, calculating a fourth parameter as a function of a difference between the amplitude AA0 of the reproduced signal obtained from the fifth track and the amplitude AA1 of the reproduced signal obtained from the fourth track,
10 comparing the critical parameter and the thus calculated fourth parameter, and obtaining a recording power at which the fourth parameter was obtained when the fourth parameter is equal to or lower than the critical parameter.

The above and other objects and features of the present invention
15 will become apparent from the following description made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic perspective view showing the structure of
20 an optical recording medium that is a preferred embodiment of the present invention.

Figure 2 is a block diagram of a data recording apparatus that is a preferred embodiment of the present invention.

Figure 3 is a flow chart showing a laser beam recording power
25 determination routine for determining the level of a recording power P_w of a pulse train pattern for modulating the power of a laser beam.

Figure 4 is a schematic plan view showing three tracks adjacent with each other in a power calibration area of an optical recording medium

in which a test signal is recorded.

Figure 5 is a flow chart showing a critical signal amplitude reduction ratio determination routine for the ratio R_c of reduction in the amplitude of a critical signal.

5 Figure 6 is a table showing a first signal amplitude reduction ratio R_1 , a second signal amplitude reduction ratio R_2 and a jitter degradation level R_3 .

Figure 7 is a graph showing a relationship between a second signal amplitude reduction ratio R_2 and a jitter degradation level R_3 .

10 Figure 8 is a graph showing a relationship between a first signal amplitude reduction ratio R_1 and a second signal amplitude reduction ratio R_2 .

DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 A preferred embodiment of the present invention will now be described with reference to accompanying drawings.

Figure 1 is a schematic perspective view showing the structure of an optical recording medium 10 that is a preferred embodiment of the present invention.

20 As shown in Figure 1, the optical recording medium 10 according to this embodiment is constituted as a data rewritable type optical recording medium and includes a substrate 11, a reflective layer 12 formed on the surface of the substrate 11, a second dielectric layer 13 formed on the surface of the reflective layer 12, a recording layer 14 formed on the
25 surface of the second dielectric layer 13, a first dielectric layer 15 formed on the surface of the recording layer 14 and a light transmission layer 16 formed on the surface of the first dielectric layer 15.

As Figure 1, a center hole 17 is formed at the center portion of the

optical recording medium 10.

As Figure 1, in this embodiment, data are recorded in the optical recording medium 10 and data are reproduced from the optical recording medium 10 by projecting a laser beam onto the surface of the light
5 transmission layer 16.

The substrate 11 serves as a support for ensuring mechanical strength required for the optical recording medium 10.

The material used to form the substrate 11 is not particularly limited insofar as the substrate 11 can serve as the support of the optical
10 recording medium 10. The substrate 11 can be formed of glass, ceramic, resin or the like. Among these, resin is preferably used for forming the substrate 11 since resin can be easily shaped. Illustrative examples of resins suitable for forming the substrate 11 include polycarbonate resin, acrylic resin, epoxy resin, polystyrene resin, polyethylene resin,
15 polypropylene resin, silicone resin, fluoropolymers, acrylonitrile butadiene styrene resin, urethane resin and the like. Among these, polycarbonate resin is most preferably used for forming the support substrate 11 from the viewpoint of easy processing, optical characteristics and the like.

In this embodiment, the substrate 11 has a thickness of about 1.1
20 mm.

The shape of the substrate 11 is not particularly limited but the substrate 11 is normally formed to be disc-like, card-like or sheet-like.

As shown in Figure 1, grooves 11a and lands 11b are alternately formed on the surface of the substrate 11. The grooves 11a and/or lands
25 11b serve as a guide track for the laser beam when data are to be recorded or when data are to be reproduced.

The reflective layer 12 serves to reflect the laser beam entering through the light transmission layer 16 so as to emit it from the light

transmission layer 16.

The thickness of the reflective layer 12 is not particularly limited but it is preferable to form the reflective layer 12 so as to have a thickness of 10 nm to 300 nm and particularly preferable to form it so as to have a
5 thickness of 20 nm to 200 nm.

The material usable for forming the reflective layer 12 is not particularly limited insofar as it can reflect a laser beam, and the reflective layer 12 can be formed of Mg, Al, Ti, Cr, Fe, Co, Ni, Cu, Zn, Ge, Ag, Pt, Au and the like. Among these materials, it is preferable to form the reflective
10 layer 12 of a metal material having a high reflectivity, such as Al, Au, Ag, Cu or alloy containing at least one of these metals, such as alloy of Ag and Ti.

The reflective layer 12 also serves to increase the difference in reflectivity between a recorded region and an unrecorded region by a
15 multiple interference effect, thereby obtaining a higher reproduced signal (C/N ratio) from data recorded in the recording layer 14.

The first dielectric layer 15 and the second dielectric layer 13 serve to protect the recording layer 14. Degradation of recorded data can be prevented over a long period by the first dielectric layer 15 and the second
20 dielectric layer 13. Further, the second dielectric layer 13 can serve to prevent the substrate 11 and the like from being thermally deformed and it is therefore to effectively prevent jitter from becoming worse due to the deformation of the substrate 11 and the like.

The material used for forming the first dielectric layer 15 and the
25 second dielectric layer 13 is not particularly limited insofar as it is a transparent dielectric material and the first dielectric layer 15 and the second dielectric layer 13 can be formed of a dielectric material containing oxide, sulfide, nitride or a combination thereof, for example, as a primary

component. In order to prevent the support substrate 11 from being deformed by heat and to protect the first recording layer 31 and the second recording layer 32, it is preferable for each of the first dielectric layer 15 and the second dielectric layer 13 to contain at least one kind of dielectric material selected from a group consisting of Al_2O_3 , AlN , ZnO , ZnS , GeN , GeCrN , CeO , CeO_2 , SiO , SiO_2 , SiN and SiC as a primary component and it is particularly preferable for it to contain $\text{ZnS} \cdot \text{SiO}_2$ as a primary component.

The first dielectric layer 15 and the second dielectric layer 13 may be formed of the same dielectric material or of different dielectric materials. Moreover, at least one of the first dielectric layer 15 and the second dielectric layer 13 may have a multi-layered structure including a plurality of dielectric films.

In this specification, the statement that a dielectric layer contains a dielectric material as a primary component means that the content of the dielectric material is largest among dielectric materials contained in the dielectric layer and $\text{ZnS} \cdot \text{SiO}_2$ means a mixture of ZnS and SiO_2 .

The thickness of the first dielectric layer 15 and the second dielectric layer 13 is not particularly limited but is preferably from 3 nm to 200 nm. If the first dielectric layer 15 or the second dielectric layer 13 is thinner than 3 nm, it is difficult to obtain the above-described advantages. On the other hand, if the first dielectric layer 15 or the second dielectric layer 13 is thicker than 200 nm, it takes a long time to form the first dielectric layers 15 and the second dielectric layers 13, thereby lowering the productivity of the optical recording medium 10, and cracks may be generated in the first dielectric layers 15 or the second dielectric layers 13 owing to stress present in the first dielectric layers 15 or the second dielectric layer 13.

The recording layer 14 is a layer in which data are to be recorded. In this embodiment, the recording layer 14 is formed of a phase change material and data are recorded in the recording layer 14 and data are reproduced from the recording layer 14 by utilizing the difference in reflectivity between the recording layer 14 in a crystalline state and the recording layer 14 in an amorphous state.

The material for forming the recording layer 14 is not particularly limited but in order to directly overwrite data at a high velocity, it is preferable for the material for forming the recording layer 14 to be changed from an amorphous state to a crystalline state in a short time, in other words, to have a short crystallization time and illustrative examples of such materials includes an SbTe system material.

The SbTe system material may be a SbTe alone or may be added with additives in order to improve long term storage reliability.

Concretely, it is preferable to form the recording layer 14 of a SbTe system material represented by a general formula: $(\text{Sb}_x\text{Te}_{1-x})_{1-y}\text{M}_y$ where M is an element other than Sb and Te, x is equal to or larger than 0.55 and equal to or smaller than 0.9 and y is equal to or larger than 0 and equal to or smaller than 0.25 and it is more preferable to form the recording layer 14 of the SbTe system material represented by the above general formula where x is equal to or larger than 0.65 and equal to or smaller than 0.85 and y is equal to or larger than 0 and equal to or smaller than 0.25.

The element M is not particularly limited but in order to shorten the crystallization time and improve long term storage reliability, it is preferable for the element M to be at least one element selected from the group consisting of In, Ag, Au, Bi, Se, Al, P, Ge, H, Si, C, V, W, Ta, Zn, Mn, Ti, Sn, Pb, Pd, N, O and rare earth elements (Sc, Y and lanthanoid) as a primary component. Particularly, in order to improve long term storage

reliability, it is preferable for the element M to be at least one element selected from the group consisting of Ag, In, Ge and rare earth elements.

It is preferable to form the recording layer 14 so as to have a thickness of 5 nm to 30 nm and is particularly preferable to form the
5 recording layer 14 so as to have a thickness of 5 nm to 20 nm.

The light transmission layer 16 is a layer through which the laser beam is transmitted and the surface thereof forms a light incidence plane of the laser beam.

It is preferable for the light transmission layer 16 to have a
10 thickness of 10 μm to 300 μm and more preferable for the light transmission layer 16 to have a thickness of 50 μm to 150 μm .

The material for forming the light transmission layer 16 is not particularly limited. In the case where the light transmission layer 16 is formed using a spin coating method or the like, it is preferable to form the
15 light transmission layer 16 of ultraviolet ray curable resin, electron beam curable resin or the like and it is more preferable to form the light transmission layer 16 of ultraviolet ray curable resin.

The light transmission layer 16 may be formed by adhering a sheet formed of light transmittable resin onto the surface of the first dielectric
20 layer 15 using an adhesive agent.

The optical recording medium 10 having the above described configuration can be manufactured as follows, for example.

First, the reflective layer 12 is formed on the surface of the substrate 11 formed with the grooves 11a and the lands 11b.

25 The reflective layer 12 can be formed by a gas phase growth process using chemical species containing elements for forming the reflective layer 12, for example. Illustrative examples of the gas phase growth processes include vacuum deposition process, sputtering process and the like.

Then, the second dielectric layer 13 is formed on the surface of the reflective layer 12.

The second dielectric layer 13 can be formed by a gas phase growth process using chemical species containing elements for forming the second
5 dielectric layer 13, for example. Illustrative examples of the gas phase growth processes include vacuum deposition process, sputtering process and the like.

Further, the recording layer 14 is formed on the surface of the second dielectric layer 13. Similarly to the second dielectric layer 13, the
10 recording layer 14 can be formed by a gas phase growth process using chemical species containing elements for forming the recording layer 14.

Then, the first dielectric layer 15 is formed on the surface of the recording layer 14. The first dielectric layer 15 can be formed by a gas phase growth process using chemical species containing elements for
15 forming the first dielectric layer 15.

Finally, the light transmission layer 16 is formed on the surface of the first dielectric layer 15. The light transmission layer 16 can be formed, for example, by applying acryl system ultraviolet ray curable resin or epoxy system ultraviolet ray curable resin whose viscosity is adjusted onto
20 the surface of the first dielectric layer 15 using a spin coating process or the like to form a coating layer and projecting an ultraviolet ray onto the coating layer to harden it.

Thus, the optical recording medium 10 has been fabricated.

described later in the form of wobbles or pre-pits.

When data are to be recorded in the optical recording medium 10 having the above described configuration, the optical recording medium 10 is set by the user in the data recording apparatus.

5 Figure 2 is a block diagram of a data recording apparatus that is a preferred embodiment of the present invention.

As shown in Figure 2, the data recording apparatus 50 includes a spindle motor 52 for rotating the optical recording medium 10, a head 53 for emitting a laser beam toward the optical recording medium 10 and receiving a laser beam reflected from the optical recording medium 10, a controller 54 for controlling the spindle motor 52 and the head 53, a laser driving circuit 55 for feeding a laser driving signal to the head 53, and a lens driving circuit 56 for feeding a lens driving signal to the head 53.

As shown in Figure 2, the controller 54 includes a focus servo circuit 15 57, a tracking servo circuit 58 and a laser control circuit 59.

When the focus servo circuit 57 is activated, the laser beam is automatically focused onto the recording layer 14 of the optical recording medium 10 and when the tracking servo circuit 58 is activated, the spot of the laser beam automatically follows the track of the optical recording 20 medium 10.

Each of the focus servo circuit 57 and the tracking servo circuit 58 has an auto-gain control function for automatically adjusting the focus gain and an auto-gain control function for automatically adjusting the tracking gain.

25 Further, the laser control circuit 59 is adapted to generate a laser driving signal to be supplied by the laser driving circuit 55.

When the optical recording medium 10 is set in the data recording apparatus, the controller 54 reads ID data and a critical signal amplitude

reduction ratio R_c used for determining the recording power P_w of the laser beam described later which are recorded in the optical recording medium 10.

In this embodiment, a linear recording velocity for data and data for setting data recording conditions including a pulse train pattern for modulating the power of the laser are determined in advance in accordance with an optical recording medium 10 and are stored in a memory (not shown) of the data recording apparatus so as to correspond to the ID data recorded in the optical recording medium 10. Therefore, the controller 54 reads the linear recording velocity for data and the pulse train pattern for modulating the power of the laser from the memory based on the thus read ID data of the optical recording medium 10 and first determines the level of a recording power P_w of the pulse train pattern for modulating the power of the laser from.

Figure 3 is a flow chart showing a laser beam recording power determination routine for determining the level of a recording power P_w of a pulse train pattern for modulating the power of a laser beam.

When the controller 54 has read the data for setting data recording conditions stored in the memory, the controller 54 sets the level of the recording power P_w to a predetermined level based on a table stored in the memory (not shown), thereby determining a recording power determination signal and outputs it together with a recording condition setting signal to the laser driving circuit 55.

The laser driving circuit 55 controls the head 53 based on the thus input recording condition setting signal and recording power determination signal and records a test signal on three tracks adjacent with each other in a power calibration area of the optical recording medium 10 using the laser beam whose power is modulated in accordance

with the pulse train pattern in which the level of the recording power P_w is set to a predetermined level (Step S1). The power calibration area is an area in which a test signal for determining the recording power P_w of the laser beam and the like are to be recorded and provided at an inner
5 circumferential portion of an optical recording medium separately from an area where data are to be recorded.

The test signal may be a single signal or a random signal.

Figure 4 is a schematic plan view showing the three tracks adjacent with each other in the calibration area of the optical recording medium 10
10 in which the test signal was recorded at Step S1.

In Figure 4, a first track is a track in which the test signal was first recorded, the second track is a track in which the test signal was secondly recorded and the third track is a track in which the test signal was last recorded.

15 Therefore, when the test signal was written in the second track, cross erasing of data may have occurred in the first track and when the test signal was written in the third track, cross erasing of data may have occurred in the second track. To the contrary, since the test signal was last written in the third track, there is no risk of cross erasing of data occurring
20 in the third track.

The controller 54 then sets the power of the laser beam to a reproducing power P_r and outputs a first data reproduction signal to the laser driving circuit 55.

When the laser driving circuit 55 receives the first data
25 reproduction signal from the controller 54, the laser driving circuit 55 projects the laser beam whose power is set to the reproducing power P_r onto the second track in the power calibration area of the optical recording medium 10, thereby reproducing the test signal recorded on the second

track (Step S2).

The controller 54 measures signal characteristics necessary for determining the recording power P_w of the laser beam such as asymmetry, a B value and the like based on the thus obtained reproduced signal (Step S3). The thus measured signal characteristics of the reproduced signal have been influenced by cross-talk from the tracks on the opposite sides thereof.

Then, the controller 54 judges whether or not the signal characteristics of the reproduced signal measured at Step S3 satisfy reference conditions (Step S4).

As a result, when the controller 54 judges that the signal characteristics of the reproduced signal measured at Step S3 do not satisfy the reference conditions, since it can be considered that the level of the recording power P_w of the laser beam set for recording the test signal is inappropriate, the controller 54 outputs a laser beam power change signal to the laser driving circuit 55 to change the recording power P_w of the laser beam and again records the test signal on the a first track, a second track and a third track (Step S5). In this case, as a first track, a second track and a third track, three tracks in which no signal is recorded and which are adjacent with each other are selected.

To the contrary, when the controller 54 judges that the signal characteristics of the reproduced signal satisfy the reference conditions, the controller 54 sets the power of the laser beam to a reproducing power P_r and a second data reproduction signal to the laser driving circuit 55.

When the laser driving circuit 55 receives the second data reproduction signal from the controller 54, the laser driving circuit 55 projects the laser beam whose power is set to the reproducing power P_r onto the second track and the third track in the power calibration area of

the optical recording medium 10, thereby reproducing the test signal recorded on the second track and the third track (Step S6).

Then, the controller 54 measures an amplitude of the thus obtained reproduced signal (Step S7). Here, the amplitude of the reproduced signal
5 corresponds to a difference in reflectivity between a region of the recording layer 14 in which a recording mark is formed and a blank region of the recording layer 14 in which no recording mark is formed and in the case where a random signal was recorded as the test signal, the difference in reflectivity between the longest recording mark and a neighboring blank
10 region was measured as an amplitude of the reproduced signal.

As described above, since the test signal recorded on the third track was not influenced by cross erasing of data while the test signal recorded on the second track may have been influenced by cross erasing of data, the amplitude D2 of the reproduced signal obtained from the second track
15 becomes smaller than the amplitude D3 of the reproduced signal obtained from the third track.

Then, the controller 54 calculates a first signal amplitude reduction ratio R1 based on the amplitude D2 of the reproduced signal obtained from the second track and the amplitude D3 of the reproduced signal obtained
20 from the third track (Step S8). The first signal amplitude reduction ratio R1 is defined as $(D3 - D2) / D3$.

Further, the controller 54 judges whether or not the thus calculated first signal amplitude reduction ratio R1 is equal to or smaller than a critical signal amplitude reduction ratio Rc determined in a method
25 described later, recorded in the optical recording medium 10 and read from the optical recording medium 10 when the optical recording medium 10 is set in the data recording apparatus (Step S9).

As a result, when the controller 54 judges that the first signal

amplitude reduction ratio $R1$ is equal to or smaller than the critical signal amplitude reduction ratio Rc , since it can be considered that the test signal has not been greatly influenced by cross erasing of data, the controller 54 determines the recording power Pw of the laser beam used for recording the test signal on the second track as an optimum recording power (Step S11).

To the contrary, when the controller 54 judges that the first signal amplitude reduction ratio $R1$ exceeds the critical signal amplitude reduction ratio Rc , since it can be considered that the test signal has been greatly influenced by cross erasing of data and it is necessary to record data using the laser beam whose recording power Pw is set to a lower level, the controller 54 sets the recording power Pw of the laser beam to a lower level and outputs a laser beam power change signal to the laser driving circuit 55 so as to record the test signal on the a first track, a second track and a third track using the laser beam whose recording power Pw is set to a lower level (Step S10). In this case, as a first track, a second track and a third track, three tracks in which no signal is recorded and which are adjacent with each other are selected.

The above described steps are repeated until the first signal amplitude reduction ratio $R1$ becomes equal to or smaller than the critical signal amplitude reduction ratio Rc and when the first signal amplitude reduction ratio $R1$ has become equal to or smaller than the critical signal amplitude reduction ratio Rc , the recording power Pw of the laser beam used for recording the test signal on the second track is determined as an optimum recording power of the laser beam (Step S11).

In this embodiment, prior to shipping the optical recording medium 10, the critical signal amplitude reduction ratio Rc is determined by the optical recording medium manufacturer at Step S9 in the following

manner and is recorded together with the data for setting recording conditions in the optical recording medium 10 in the form of wobbles or pre-pits.

Figure 5 is a flow chart showing a critical signal amplitude reduction ratio determination routine for the critical signal amplitude reduction ratio R_c .

A variable i is first set to zero (Step S21).

Then, a pulse train pattern used for modulating the power of the laser beam and a linear recording velocity used when data are to be recorded in the optical recording medium 10 are determined and the recording power P_w of the laser beam is set to the minimum level $P_w(\min)$ determined in advance (Step S22). The laser beam is then projected onto a first track, a second track and a third track adjacent with each other in the power calibration area of the optical recording medium 10, thereby recording a test signal thereon (Step S23).

Here, similarly to in Figure 4, a first track is a track in which the test signal was first recorded, the second track is a track in which the test signal was secondly recorded and the third track is a track in which the test signal was last recorded.

The test signal may be a single signal or a random signal.

Then, the test signal recorded on the second track and the test signal recorded on the third track are reproduced (Step S24) and jitter and an amplitude of each of the thus reproduced signals are measured (Step S25).

While the jitter J_0 and the amplitude A_0 of the reproduced signal obtained by reproducing the test signal recorded on the third track are not influenced by cross erasing of data, the jitter J_1 and the amplitude A_1 of the reproduced signal obtained by reproducing the test signal recorded on

the second track have been once influenced by cross erasing of data from the third track. Therefore, the jitter J1 of the reproduced signal obtained by reproducing the test signal recorded on the second track is normally higher than the jitter J0 of the reproduced signal obtained by reproducing the test signal recorded on the third track and the amplitude A1 of the reproduced signal obtained by reproducing the test signal recorded on the second track is normally smaller than the amplitude A0 of the reproduced signal obtained by reproducing the test signal recorded on the third track.

Then, the variable i is incremented by one, namely, i is set to $(i + 1)$ (Step S26) and the test signal recorded on the first track and the test signal recorded on the third track are directly overwritten with the test signals under the same recording conditions as those used for recording the test signals at Step 23 (Step S27).

As a result, the test signal recorded on the second track is once influenced by cross erasing of data from the first track and has been twice influenced by cross erasing of data from the third track and therefore, in the case where the test signal recorded on the second track is reproduced, the jitter J2 of the thus obtained reproduced signal is much higher than the jitter J1 and the amplitude A2 of the reproduced signal is much smaller than the amplitude A1.

Step S26 and Step S27 are repeated until the variable i becomes 9, in other words, until the test signal recorded on the first track and the test signal recorded on the third track have been directly overwritten nine times and when the variable i has become 9 and the test signal recorded on the first track and the test signal recorded on the third track have been directly overwritten nine times, the test signal recorded on the second track is reproduced (Step S29) and jitter J10 and an amplitude A10 of the thus obtained reproduced signal are measured (Step S30).

The thus measured jitter J10 and amplitude A10 of the reproduced signal have been influenced by cross erasing of data nine times from the first track and influenced by cross erasing of data ten times from the third track.

5 Therefore, the jitter J10 of the reproduced signal obtained by reproducing the test signal recorded on the second track is normally much higher than the jitter J1 and the amplitude A10 of the reproduced signal obtained by reproducing the test signal recorded on the second track is normally much smaller than the amplitude A1. Here, since the test signal
10 recorded on the first track and the test data recorded on the third track have been directly overwritten nine times, the influences by cross erasing of data on the jitter J10 and the amplitude A10 have been saturated.

Further, the level of the recording power P_w of the laser beam is set to $(P_w + \alpha)$ (Step S31). Then, Step S21 to Step S31 are repeated and jitter
15 J0, J1 and J10 and amplitudes A0, A1 and A10 of the reproduced signals obtained by reproducing the test signals recorded on the second track using each of the recording powers P_w are measured.

Thus, when it is judged that the level of the recording power P_w of the laser beam exceeds the maximum level $P_w(max)$ determined in
20 advance (Step S32), the measurement of the jitter J0, J1 and J10 and the amplitudes A0, A1 and A10 of the reproduced signals obtained by reproducing the test signals recorded on the second track for each of the levels of the recording power P_w of the laser beam is completed.

Then, based on the thus measured jitter J0, J1 and J10 and
25 amplitudes A0, A1 and A10 of the reproduced signals corresponding to the respective recording powers P_w of the laser beam, a first signal amplitude reduction ratio R1, a second signal amplitude reduction ratio R2 and a jitter degradation level R3 corresponding to each of the recording powers

P_w of the laser beam are calculated and a table T shown in shown in Figure 6 is produced (Step S33).

Here, the first signal amplitude reduction ratio R1 is defined as $(A0 - A1) / A0$, the amplitude A0 corresponds to an amplitude D3 of a reproduced signal obtained by reproducing the test signal recorded on the third track at Step S7 of the laser beam recording power determination routine shown in Figure 3 and the amplitude A1 corresponds to an amplitude D3 of a reproduced signal obtained by reproducing the test signal recorded on the third track at Step S7 of the laser beam recording power determination routine shown in Figure 3.

Further, the second signal amplitude reduction ratio R2 is defined as $(A1 - A10) / A1$ and the jitter degradation level R3 is defined as $(J10 - J1)$.

When the table T has been produced in this manner, based on the thus produced table T, a first graph showing the relationship between the second signal amplitude reduction ratio R2 and the jitter degradation level R3 is produced by plotting values of the second signal amplitude reduction ratio R2 and the jitter degradation level R3 (Step S34).

Figure 7 is a first graph showing the relationship between the second signal amplitude reduction ratio R2 and the jitter degradation level R3. As shown in Figure 7, the relationship between the second signal amplitude reduction ratio R2 and the jitter degradation level R3 can be normally approximated by a linear function.

Similarly, based on the thus produced table T, a second graph showing the relationship between the signal amplitude reduction ratio R1 and the signal amplitude reduction ratio R2 is produced by plotting values of the signal amplitude reduction ratio R1 and the signal amplitude reduction ratio R2 (Step S35).

Figure 8 is a second graph showing the relationship between the signal amplitude reduction ratio R1 and the signal amplitude reduction ratio R2. As shown in Figure 8, the relationship between the signal amplitude reduction ratio R1 and the signal amplitude reduction ratio R2
5 can be normally approximated by a quadratic function.

When the first graph showing the relationship between the second signal amplitude reduction ratio R2 and the jitter degradation level R3 and the second graph showing the relationship between the signal amplitude reduction ratio R1 and the signal amplitude reduction ratio R2
10 have been produced in this manner, a value b of the second signal amplitude reduction ratio R2 corresponding to a value a of the allowable maximum jitter degradation level R3 is obtained based on the first graph shown in Figure 7 and a value c of the signal amplitude reduction ratio R1 corresponding to the value b of the second signal amplitude reduction ratio
15 R2 is obtained based on the second graph shown in Figure 8, thereby determining the value c of the signal amplitude reduction ratio R1 as a critical signal amplitude reduction ratio R_c .

Since the jitter degradation level R3 is defined as the difference between the jitter J10 of the reproduced signal obtained by reproducing
20 the test signal recorded on the second track after directly overwriting the test signal recorded on the first track and the test signal recorded on the third track with the test signal nine times and the jitter J1 of the reproduced signal obtained by reproducing the test signal recorded on the second track after recording the test signal on the first track and recording
25 the test signal on the third track, and it can be considered that when the test signal recorded on the first track and the test signal recorded on the third track have been directly overwritten with the test signal nine times, the influence of cross erasing of data on the test signal recorded on the

second track has been saturated, the thus determined critical signal amplitude reduction ratio R_c corresponds to a critical jitter degradation level R_3 at which the degradation of jitter can be permitted even when the test signal has been repeatedly influenced by cross erasing of data until
5 the influence of cross erasing of data has been saturated. Therefore, it is possible to determine an optimum power of the recording power P_w of the laser beam with which the increase in jitter of a reproduced signal can be controlled within tolerance by judging whether or not the first signal amplitude reduction ratio R_1 is equal to or smaller than a critical signal
10 amplitude reduction ratio R_c at Step S9 of the laser beam recording power determination routine shown in Figure 3.

When the optimum power of the recording power P_w of the laser beam has been determined in this manner, as shown in Figure 1, the laser beam whose power is modulated in accordance with a pulse train pattern
15 whose recording power P_w is set to the optimum power is projected onto the optical recording medium 10 from the side of the light transmission layer 16, thereby recording data in the recording layer 14 of the optical recording medium 10.

In this embodiment, the pulse train pattern includes pulses whose
20 levels are set to a recording power P_w and a bottom power P_b .

When a recording mark is to be formed in the recording layer 14, a laser beam whose power is set to the P_w is projected onto a region of the recording layer 14 where the recording mark is to be formed.

As a result, a phase change material contained in the region of the
25 recording layer 14 irradiated with the laser beam is heated to a temperature equal to or higher than the melting point thereof.

Then, the laser beam whose power is set to the bottom power P_b lower than the P_w is projected onto the region of the recording layer 14

where the recording mark is to be formed.

As a result, the phase change material heated to the temperature equal to or higher than the melting point thereof and melted is quickly cooled and the phase thereof is changed to an amorphous phase, thereby
5 forming the recording mark in the recording layer.

To the contrary, when a recording mark formed in the recording layer 14 is to be erased, the laser beam whose power is set to an erasing power P_e is projected onto a region of the recording layer 14 where the recording mark is formed. Here, P_e is higher than P_b and lower than P_w .

10 As a result, a phase change material contained in the region of the recording layer 14 irradiated with the laser beam is heated to a temperature equal to or higher than the crystallization temperature thereof.

Then, the laser beam is moved away and the region of the recording
15 layer 14 heated to the temperature equal to or higher than the crystallization temperature of the phase change material is gradually cooled. As a result, the region of the recording layer 14 in an amorphous state is crystallized, whereby the recording mark formed in the recording layer 14 is erased.

20 Therefore, it is possible to form a recording mark in the recording layer 14 and erase a recording mark formed in the recording layer 14 by modulating the power of the laser beam and it is further possible to form a different recording mark at the region of the recording layer 14 where a recording mark is formed and directly overwrite data recorded in the
25 recording layer 14 with different data by modulating the power of the laser beam between the recording power P_w , the bottom power P_b and the erasing power P_e .

Thus, data are recorded in the recording layer 14 of the optical

recording medium 10 by utilizing the difference in reflectivity between the case where the region of the recording layer 14 is in an amorphous phase and the case where the region of the recording layer 14 is in a crystalline phase.

5 According to this embodiment, prior to shipping a optical recording medium 10, since a critical signal amplitude reduction ratio R_c is determined and recorded in the optical recording medium 10 by the optical recording medium manufacturer, it is possible to set the recording power P_w of a laser beam to an optimum power with a simple operation in a short
10 time when data are to be recorded in the optical recording medium 10 and it is therefore possible to reduce the burden of the user.

 Further, according to this embodiment, based on the first graph showing the relationship between the second signal amplitude reduction ratio R_2 defined as $(A_1 - A_{10}) / A_1$ and the jitter degradation level R_3
15 defined as $(J_{10} - J_1)$, a value b of the second signal amplitude reduction ratio R_2 corresponding to a value a of the permissible maximum jitter degradation level R_3 is obtained and based on the second graph showing the relationship between the first signal amplitude reduction ratio R_1 is defined as $(A_0 - A_1) / A_0$ and the second signal amplitude reduction ratio
20 R_2 , a value c of the signal amplitude reduction ratio R_1 corresponding to the value b of the second signal amplitude reduction ratio R_2 is obtained, thereby determining the value c of the signal amplitude reduction ratio R_1 as a critical signal amplitude reduction ratio R_c . Further, the jitter degradation level R_3 is defined as the difference between the jitter J_{10} of
25 the reproduced signal obtained by reproducing the test signal recorded on the second track after directly overwriting the test signal recorded on the first track and the test signal recorded on the third track with the test signal nine times and the jitter J_1 of the reproduced signal obtained by

reproducing the test signal recorded on the second track after recording the test signal on the second track and recording the test signal on the third track, and it can be considered that when the test signal recorded on the first track and the test signal recorded on the third track have been
5 directly overwritten with the test signal nine times, the influence of cross erasing of data on the test signal recorded on the second track has been saturated. Therefore, since the thus determined critical signal amplitude reduction ratio R_c corresponds to a critical jitter degradation level R_3 at which the increase in the degradation of jitter can be permitted even when
10 the test signal has been repeatedly influenced by cross erasing of data until the influence of cross erasing of data has been saturated, it is possible to determine an optimum power of the recording power P_w of the laser beam so as to control the increase in jitter of a reproduced signal within tolerance by judging whether or not the first signal amplitude reduction
15 ratio R_1 is equal to or smaller than a critical signal amplitude reduction ratio R_c at Step S9 of the laser beam recording power determination routine shown in Figure 3.

The present invention has thus been shown and described with reference to a specific embodiment and a working example. However, it
20 should be noted that the present invention is in no way limited to the details of the described arrangements but changes and modifications may be made without departing from the scope of the appended claims.

For example, in the above described preferred embodiment, although the critical signal amplitude reduction ratio determination
25 routine is performed by the optical recording medium manufacturer, thereby determining the critical signal amplitude reduction ratio R_c and recording the thus determined critical signal amplitude reduction ratio R_c in the optical recording medium 10, the critical signal amplitude reduction

ratio R_c recorded in the optical recording medium 10 is read by the data recording apparatus when data are to be recorded in the optical recording medium 10 and the laser beam recording power determination routine is performed, it is sufficient for the critical signal amplitude reduction ratio
5 determination routine to be performed prior to performing the laser beam recording power determination routine and it is not absolutely necessary for the optical recording medium manufacturer to perform the critical signal amplitude reduction ratio determination routine. Therefore, the critical signal amplitude reduction ratio determination routine may be
10 performed by the data recording apparatus prior to performing the laser beam recording power determination routine.

Furthermore, in the above described preferred embodiment, although the critical signal amplitude reduction ratio determination routine is performed by the optical recording medium manufacturer,
15 thereby determining the critical signal amplitude reduction ratio R_c and recording the thus determined critical signal amplitude reduction ratio R_c in the optical recording medium 10, the critical signal amplitude reduction ratio R_c recorded in the optical recording medium 10 is read by the data recording apparatus when data are to be recorded in the optical recording
20 medium 10 and the laser beam recording power determination routine is performed, it is sufficient for the laser beam recording power determination routine to be performed after performing the critical signal amplitude reduction ratio determination routine and it is not absolutely necessary for the data recording apparatus to perform the laser beam
25 recording power determination routine. Therefore, the laser beam recording power determination routine may be performed by the optical recording medium manufacturer after performing the critical signal amplitude reduction ratio determination routine. In such a case, it is

preferable to constitute so that an optimum power of the recording power P_w of the laser beam is recorded in the optical recording medium 10 prior to shipping the optical recording medium 10 and the optimum power of the recording power P_w of the laser beam recorded in the optical recording
5 medium 10 is read by the data recording apparatus, whereby the power of the laser beam is set to the optimum power and data are recorded in the optical recording medium 10.

Moreover, in the above described preferred embodiment, although the ID data and the critical signal amplitude reduction ratio R_c are
10 recorded in the optical recording medium 10 and when data are to be recorded in the optical recording medium 10, the data recording apparatus reads the ID data recorded in the optical recording medium 10, reads the linear data recording velocity and the pulse train pattern for modulating the power of the laser beam stored in the memory so as to be associated
15 with the ID data of the optical recording medium 10 and reads the critical signal amplitude reduction ratio R_c recorded in the optical recording medium 10, thereby performing the laser beam recording power determination routine and determining an optimum power of the recording power P_w of the laser beam, it is possible to calculate the critical
20 signal amplitude reduction ratio R_c in advance and store the critical signal amplitude reduction ratio R_c in the memory of the data recording apparatus so as to be associated with the ID data of the optical recording medium 10, and to constitute the data recording apparatus so as to read the ID data recorded in the optical recording medium 10, read the critical
25 signal amplitude reduction ratio R in addition to the linear data recording velocity and the pulse train pattern for modulating the power of the laser beam and determine an optimum power of the recording power P_w of the laser beam. In such a case, it is unnecessary to record the critical signal

amplitude reduction ratio R_c in the optical recording medium 10 and it is possible to effectively utilize the capacity of the optical recording medium 10.

Further, in the above described preferred embodiment, although
5 the ID data and the critical signal amplitude reduction ratio R_c are recorded in the optical recording medium 10 and when data are to be recorded in the optical recording medium 10, the data recording apparatus reads the ID data recorded in the optical recording medium 10, reads the linear data recording velocity and the pulse train pattern for modulating
10 the power of the laser beam stored in the memory so as to be associated with the ID data of the optical recording medium 10 and reads the critical signal amplitude reduction ratio R_c recorded in the optical recording medium 10, thereby performing the laser beam recording power determination routine and determining an optimum power of the
15 recording power P_w of the laser beam, it is possible to calculate the critical signal amplitude reduction ratio R_c in advance, determine an optimum power of the recording power P_w of the laser beam based on the thus calculated critical signal amplitude reduction ratio R_c and store the critical signal amplitude reduction ratio R_c in the memory of the data
20 recording apparatus so as to be associated with the ID data of the optical recording medium 10, and to constitute the data recording apparatus so as to read the ID data recorded in the optical recording medium 10, read the optimum power of the recording power P_w of the laser beam in addition to the linear data recording velocity and the pulse train pattern for
25 modulating the power of the laser beam and determines an optimum power of the recording power P_w of the laser beam. In such a case, since it is unnecessary to record the critical signal amplitude reduction ratio R_c in the optical recording medium 10, it is possible to effectively utilize the

capacity of the optical recording medium 10 and the data recording apparatus can immediately record data in the optical recording medium 10 without performing the laser beam recording power determination routine when data are to be recorded in the optical recording medium 10.

5 Furthermore, in the above described preferred embodiment, although the ID data and the critical signal amplitude reduction ratio R_c are recorded in the optical recording medium 10 and when data are to be recorded in the optical recording medium 10, the data recording apparatus reads the ID data recorded in the optical recording medium 10, reads the
10 linear data recording velocity and the pulse train pattern for modulating the power of the laser beam stored in the memory so as to be associated with the ID data of the optical recording medium 10 and reads the critical signal amplitude reduction ratio R_c recorded in the optical recording medium 10, thereby performing the laser beam recording power
15 determination routine and determining an optimum power of the recording power P_w of the laser beam, it is possible to store the table T shown in Figure 6 in the optical recording medium 10 instead of the critical signal amplitude reduction ratio R_c and constitute the data recording apparatus so as to read the table T recorded in the optical
20 recording medium 10, perform the critical signal amplitude reduction ratio determination routine, thereby calculating the critical signal amplitude reduction ratio R_c , perform the laser beam recording power determination routine using the thus calculated critical signal amplitude reduction ratio R_c , thereby determining the optimum power of the recording power P_w of
25 the laser beam. In such a case, it is possible to constitute the data recording apparatus so as to store an program for performing the critical signal amplitude reduction ratio determination routine and perform the critical signal amplitude reduction ratio determination routine in

accordance with the stored program or it is possible to store an program for performing the critical signal amplitude reduction ratio determination routine in the optical recording medium 10 and constitute the data recording apparatus so as to read the program stored in the optical recording medium 10 and perform the critical signal amplitude reduction ratio determination routine.

Moreover, in the above described preferred embodiment, although the ID data and the critical signal amplitude reduction ratio R_c are recorded in the optical recording medium 10, when data are to be recorded in the optical recording medium 10, the data recording apparatus reads the ID data recorded in the optical recording medium 10, reads the linear data recording velocity and the pulse train pattern for modulating the power of the laser beam stored in the memory so as to be associated with the ID data of the optical recording medium 10 and reads the critical signal amplitude reduction ratio R_c recorded in the optical recording medium 10, thereby performing the laser beam recording power determination routine and determining an optimum power of the recording power P_w of the laser beam, and a program for performing the laser beam recording power determination routine, it is not absolutely necessary for the data recording apparatus to store a program for performing the laser beam recording power determination routine and it is possible to store a program for performing the laser beam recording power determination routine in the optical recording medium 10 and constitute the data recording apparatus so as to read the program for performing the laser beam recording power determination routine and perform the laser beam recording power determination routine.

Further, in the above described preferred embodiment, although the test signal recorded on the second track is reproduced after directly

overwriting the test data recorded on the first track and the test data recorded on the third track with the test data nine times, it is sufficient to reproduce the test signal recorded on the second track after directly overwriting the test data recorded on the first track and the test data recorded on the third track with the test data until the influence of cross erasing of data on the test signal recorded on the second track has been saturated and it is not absolutely necessary to reproduce the test signal recorded on the second track after directly overwriting the test data recorded on the first track and the test data recorded on the third track with the test data nine times.

Furthermore, in the above described preferred embodiment, although the laser beam recording power determination routine is performed by increasing the recording power P_w of the laser beam from the minimum power $P_w(min)$ determined in advance by α , it is sufficient to perform the laser beam recording power determination routine by changing the recording power P_w of the laser beam between the maximum power $P_w(max)$ and the minimum power $P_w(min)$ of the laser beam determined in advance and how to change the recording power P_w of the laser beam is not particularly limited.

Moreover, in the above described preferred embodiment, although the test signal is recorded using the first signal amplitude reduction ratio $R1$ defined as $(A0 - A1) / A0$ and thereafter, the difference between the amplitude $A0$ of the reproduced signal obtained by reproducing the test signal recorded on the third track and the amplitude $A1$ of the reproduced signal obtained by reproducing the test signal recorded on the second track is evaluated, it is possible to record a test signal based on, instead of the first signal amplitude reduction ratio $R1$, a first signal amplitude reduction parameter defined as a function of the difference between the

amplitude A0 of a reproduced signal obtained by reproducing a test signal recorded on a third track after recording the test signal on a first track, a second track and third track in this order and the amplitude A1 of a reproduced signal obtained by reproducing the test signal recorded on the second track, and thereafter evaluate the difference between the amplitude A0 of the reproduced signal obtained by reproducing the test signal recorded on the third track and the amplitude A1 of the reproduced signal obtained by reproducing the test signal recorded on the second track.

Further, in the above described preferred embodiment, although the test signal is recorded using the second signal amplitude reduction ratio R2 defined as $(A1 - A10) / A1$ and thereafter, the difference between the amplitude A1 of the reproduced signal obtained by reproducing the test signal recorded on the second track and the amplitude A10 of the reproduced signal obtained by reproducing the test signal recorded on the second track after directly overwriting the test signal recorded on the first track and the test signal recorded on the third track with the test signal nine times is evaluated, it is possible to record a test signal based on, instead of the second signal amplitude reduction ratio R2, a second signal amplitude reduction parameter defined as a function of the difference between the amplitude A1 of a reproduced signal obtained by reproducing the test signal recorded on the second track after recording the test signal on a first track, a second track and third track in this order and the amplitude A10 of a reproduced signal obtained by reproducing the test signal recorded on the second track after directly overwriting the test signal recorded on the first track and the test signal recorded on the third track with the test signal nine times, and evaluate the difference between the amplitude A1 of a reproduced signal obtained by reproducing the test

signal recorded on the second track and the amplitude A10 of the reproduced signal obtained by reproducing the test signal recorded on the second track after directly overwriting the test signal recorded on the first track and the test signal recorded on the third track with the test signal
5 nine times.

Furthermore, in the above described preferred embodiment, although the jitter degradation level R3 is defined as $(J10 - J1)$, it is sufficient for a jitter degradation level R3 to be defined as a function of the difference between jitter J10 of a reproduced signal obtained by
10 reproducing a test signal recorded on a second track after directly overwriting a test signal recorded on a first track and the test signal recorded on a third track with the test signal nine times and jitter J1 of a reproduced signal obtained by reproducing a test signal recorded on the second track after recording the test signal on the first track, the second
15 track and the third track in this order. Therefore, it is not absolutely necessary to define a jitter degradation level R3 as $(J10 - J1)$ and the jitter degradation level R3 may be defined as $(J10 - J1) / J10$ or $(J10 - J1) / J1$.

According to the present invention, it is possible to provide a method for determining the power of a laser beam which can determine
20 the recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded in a data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

25 Further, according to the present invention, it is possible to provide a method for determining a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam to be projected onto a data rewritable type optical recording

medium so that jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

5 Furthermore, according to the present invention, it is possible to provide a data rewritable type optical recording medium in which a critical parameter used for determining the power of a laser beam which can determine the recording power of the laser beam so that jitter of a reproduced signal obtained by reproducing data recorded therein can be
10 controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.

 Moreover, according to the present invention, it is possible to provide a data recording apparatus storing a critical parameter used for determining the power of a laser beam which can determine the recording
15 power of the laser beam to be projected onto a data rewritable type optical recording medium so that jitter of a reproduced signal obtained by reproducing data recorded in the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be
20 obtained.

 Further, according to the present invention, it is possible to provide a data recording apparatus storing an optimum recording power of a laser beam to be projected onto a data rewritable optical recording medium so that jitter of a reproduced signal obtained by reproducing data recorded in
25 the data rewritable type optical recording medium can be controlled within a tolerance even when cross erasing of data occurs and that the reproduced signal having the highest level can be obtained.